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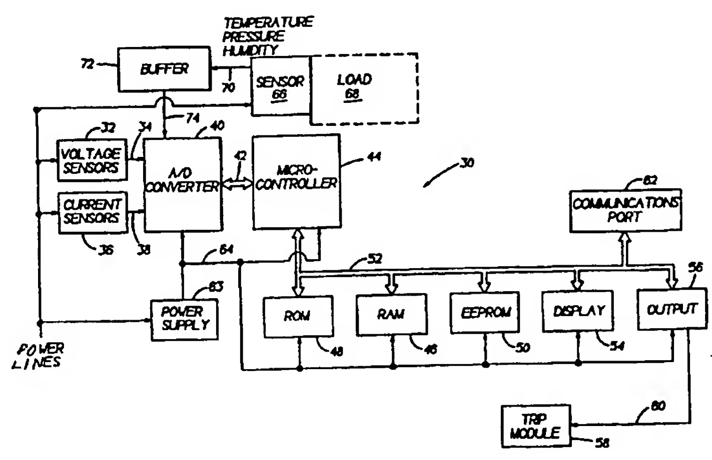
(54) Title: AN INTELLIGENT ELECTRONIC DEVICE FOR MONITORING NON-ELECTRICAL CHARACTERISTICS



(57) Abstract: A method of monitoring non-electrical characteristics, i.e., temperature, humidity of pressure, of a protected load in an intelligent electronic device is presented. The method senses a non-electrical characteristic of the protected load to provide a sensed non-electrical characteristic signal indicative of the non-electrical characteristic. The method processes the non-electrical characteristic signal to provide a relationship of the non-electrical characteristic signal. In an exemplary embodiment of the invention, the relationship of the non-electrical characteristic signal is compared to user defined thresholds to detect non-electrical fault conditions. For example, such non-electrical fault conditions may not exceed 85°C or 90% relative humidity. In an alternative exemplary embodiment of the invention, the relationship of the non-electrical characteristic signal is processed for analysis purposes. The data is analyzed within the electronic trip unit itself, or alternatively communicated to a remote monitoring device, e.g., a computer.

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AN INTELLIGENT ELECTRONIC DEVICE FOR MONITORING NON-ELECTRICAL CHARACTERISTICS

BACKGROUND OF THE INVENTION

The present invention relates generally to intelligent electronic devices, e.g., electronic trip units, protective relays, energy meters, power analyzers, motor control center controllers and programmable logic controllers. More specifically, the present invention relates to a method of monitoring non-electrical characteristics in an intelligent electronic device.

An electronic trip unit, an example of one such intelligent electronic device, typically comprises voltage and current sensors, which provide analog signals indicative of the power line signals. The analog signals are converted by an A/D (analog/digital) converter to digital signals which are processed by a microprocessor. The trip unit further includes RAM (random access memory), ROM (read only memory) and EEPROM (electronic erasable programmable read only memory) all of which interface with the microprocessor. The ROM includes trip unit application code, e.g., main functionality firmware, including initializing parameters, and boot code. The EEPROM includes operational parameters for the application code.

Intelligent electronic devices protect various types of loads, e.g., electric motors, electric motor drives, transformers, and furnaces. Intelligent electronic devices typically monitor electrical characteristics of the protected loads via their voltage and current sensors. In a large facility, e.g., a manufacturing plant, many hundreds of intelligent electronic devices may be used to protect an even larger number of loads. Often the intelligent electronic devices are connected together though a communications network, e.g., a power

management control system such as General Electric's Power Leader, to a computer or other remote monitoring device.

When an electrical fault condition is detected, e.g., voltage or current rising above a predetermined threshold, the intelligent electronic device determines a protective action based on preset programming. For example, the intelligent electronic device may initiate a circuit breaker trip, trigger an alarm, display the status of the load via local display monitor or send an event message to a remote monitoring device.

However, safety and/or functionality of a protected load often depends on monitoring and maintaining non-electrical characteristics, e.g., temperature, humidity, and pressure, within acceptable threshold limits. For example, protected loads are often rated to operate at less than 85°centigrade and 90% relative humidity. Additionally, monitoring non-electrical characteristics are useful for analysis purposes as well, e.g., predicting most likely future non-electrical faults, prioritizing maintenance requirements of protected loads or determining load life and load component wear.

Prior art intelligent electronic devices are unable to monitor non-electrical characteristics. Therefore they cannot analyze non-electrical characteristics, nor can they protect a load from non-electrical fault conditions, e.g., a non-electrical characteristic reaching a predetermined threshold. Consequently, additional protective devices, e.g., temperature controllers and dehumidifiers, are required to separately communicate with the protected load and/or an operator. In a large facility, these additional protective devices would require a separate communications network independent of the intelligent electronic devices' network.

BRIEF SUMMARY OF THE INVENTION

In an exemplary embodiment of the invention, a method of monitoring a non-electrical characteristic in an intelligent electronic device is presented. The method generates a non-electrical characteristic signal indicative of a non-electrical characteristic of a protected load. The method compares a relationship of the non-electrical characteristic signal with a predetermined threshold indicative of a non-electrical fault condition. The method generates a protective action signal when the predetermined threshold is reached.

In an alternative embodiment of the invention, an intelligent electronic device for monitoring non-electrical characteristics comprises a sensor and a signal processor. The sensor generates a non-electrical characteristic signal indicative of the non-electrical characteristic of a protected load. The signal processor is responsive to the non-electrical characteristic signal, and has a memory for storing signals including program signals defining an executable program. The program compares a relationship of the non-electrical characteristic signal with a predetermined threshold indicative of a non-electrical fault condition. The program generates a protective action signal when the predetermined threshold is reached.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings wherein the Figure is a schematic block diagram of an electronic trip unit.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figure, a general schematic of an electronic trip unit is generally shown at 30. It will be appreciated that the present invention is not limited to electronic trip units but is directed to intelligent electronic devices in general. Trip unit 30 comprises a voltage sensor 32 which provides analog signals indicative of voltage measurements on a signal line 34 and a current sensor 36 which provides analog signals indicative of a current measurements on a signal line 38. The analog signals on lines 34 and 38 are presented to an A/D (analog/digital) converter 40, which converts these analog signals to digital signals. The digital signals are transferred over a bus 42 to a microprocessor (signal processor) 44, such being commercially available from the Hitachi Electronics Components Group (Hitachi's H8/300 family of microprocessors). Trip unit 30 further includes RAM (random access memory) 46, ROM (read only memory) 48 and EEPROM (electronic erasable programmable read only memory) 50 all of which communicate with the microprocessor 44 over a control bus 52. It will be appreciated that A/D converter 40, ROM 48, RAM 46, or any combination thereof may be internal to microprocessor 44, as is well known. EEPROM 50 is non-volatile so that system information and programming will not be lost during a power interruption or outage. Data, typically status of the circuit breaker, is displayed by a display 54 in response to display signals received from microprocessor 44 over control bus 52. An output control device 56, in response to control signals received from microprocessor 44 over control bus 52, controls a trip module 58 via a line 60. Trip module 58 controls separable contacts of a circuit breaker (not shown). When trip unit 30 detects a fault condition, trip module 58 will separate the contacts (a circuit breaker trip event) to interrupt current to a protected circuit such as load 68. Calibration, testing, programming and other features are accomplished through a communications I/O port 62, which communicates with microprocessor 44 over

control bus 52. A power supply 63 which is powered by the service electricity, provides appropriate power over a line 64 to the components of trip unit 30. ROM 48 includes trip unit application code, e.g., main functionality firmware, including initializing parameters, and boot code. The application code includes code for a monitoring method (algorithm) in accordance with the present invention.

EEPROM 50 includes operational parameter code, e.g., code for setting user defined parameters such as non-electrical fault condition thresholds, or action paths such as trip, alarm or status. These parameters may be stored in the trip unit at the factory and are selected to meet customers' requirements, but can also be remotely downloaded as described hereinafter. The monitoring algorithm is run in real-time and is initiated preferably from the boot code at start up.

Non-electronic sensor 66 is mounted to a protected load 68 which is external to the electronic trip unit 30. Sensor 66 monitors a desired non-electrical characteristic, e.g., temperature, pressure or humidity, at the load. Sensor 66 provides analog signals indicative of the non-electrical characteristic on a signal line 70. The analog signals on line 70 are presented to an isolation buffer 72 which performs various protective functions, i.e., noise isolation protection, or protection from voltage swings outside of the operating parameters of low voltage components such as the microprocessor 44. By way of example, buffer 72 is shown external to trip unit 30. However, it will be understood by one skilled in the art that buffer 72 may also be internal to trip unit 30 as well. Buffer 72 provides a buffered analog signal indicative of the non-electrical characteristic on a signal line 74. The buffered analog signal is presented to the A/D converter 40, which converts this analog signal to a digital signal indicative of the non-

electrical characteristic. The digital non-electrical characteristic signal is transferred over bus 42 to microprocessor 44 for further processing.

In an exemplary embodiment of the invention, microprocessor 44 compares a relationship (processed) of the non-electrical characteristic signal to user defined thresholds to detect non-electrical fault conditions. For example, such non-electrical fault conditions may be to not exceed 85°C or 90% relative humidity. When a defined threshold of the non-electrical fault condition is reached, the microprocessor 44 generates a signal to initiate a pre-programmed protective action. For example, a protective action may include initiating a circuit breaker trip event, triggering an alarm, displaying the status of the protected load on a monitor, or sending an event message to a remote monitoring device.

In an alternative exemplary embodiment of the invention, the relationship of the non-electrical characteristic is processed by microprocessor 44 for analysis purposes. The data is analyzed within the electronic trip unit itself, or alternatively communicated to a remote monitoring device, e.g., a computer, through communications I/O port 62. It will be appreciated that such analysis purposes may included predicting most likely future non-electrical faults, prioritizing maintenance requirements of protected loads or determining load life and load component wear. It will also be appreciated that the communications I/O port 62 may communicate through a network, e.g., a power management control system such as General Electric's Power Leader, to the remote monitoring device.

All of the aforementioned limits or settings are preferably stored in EEPROM 50 and can be altered by downloading desired settings via communications I/O port 62. This would include remotely downloading such

data when the unit is connected to a system computer (not shown), either directly, over telephone lines, or any other suitable connection. It may also be preferred that EEPROM 50 comprises a flash memory whereby such data is flashed, as is well known.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

WHAT IS CLAIMED IS:

1. A method of monitoring a non-electrical characteristic in an intelligent electronic device, said method comprising:

generating a non-electrical characteristic signal indicative of a non-electrical characteristic of a protected load;

comparing a relationship of said non-electrical characteristic signal with a predetermined threshold indicative of a non-electrical fault condition; and

generating a protective action signal when said predetermined threshold is reached.

2. The method of claim 1 wherein said comparing comprises buffering said non-electrical characteristic signal.

3. The method of claim 1 wherein said comparing comprises converting said non-electrical characteristic signal to a digital signal.

4. The method of claim 1 wherein said comparing comprises communicating said relationship of said non-electrical characteristic to a remote monitoring device.

5. The method of claim 1 wherein said generating a protective action signal comprises at least one of initiating a trip event, triggering an alarm, displaying status of said protected load and communicating said protective action signal to a centralized monitoring station.

6. The method of claim 1 wherein said non-electrical characteristic comprises at least one of a humidity, a temperature and a pressure.

7. The method of claim 1 wherein said non-electrical characteristic signal comprises an analog signal.

8. The method of claim 1 wherein said intelligent electronic device comprises an electronic trip unit.

9. A method of monitoring a non-electrical characteristic in an intelligent electronic device, said method comprising:

generating a non-electrical characteristic signal indicative of a sensed non-electrical characteristic of a protected load;

processing a relationship of said non-electrical characteristic signal for analysis purposes; and

generating an action signal when a predetermined analytical threshold is reached.

10. The method of claim 9 wherein said processing includes at least one of:

predicting most likely future non-electrical faults,

prioritizing maintenance requirements of protected loads, and

determining load life.

11. The method of claim 9 wherein said processing comprises communicating said relationship of said non-electrical characteristic to a remote monitoring device.

12. An intelligent electronic device for monitoring non-electrical characteristics, said intelligent electronic device comprising:

a sensor generating a non-electrical characteristic signal indicative of said non-electrical characteristic of a protected load; and

a signal processor responsive to said non-electrical characteristic signal, and having a memory for storing signals including program signals defining an executable program for:

comparing a relationship of said non-electrical characteristic signal with a predetermined threshold indicative of a non-electrical fault condition, and

generating a protective action signal when said predetermined threshold is reached.

13. The intelligent electronic device of claim 12 further comprising a buffer for conditioning said non-electrical characteristic signal.

14. The intelligent electronic device of claim 12 further comprising an analog to digital converter for converting said non-electrical characteristic signal to a digital signal.

15. The intelligent electronic device of claim 12 further comprising a communication port for communicating said relationship of said non-electrical characteristic to a remote monitoring device.

16. The intelligent electronic device of claim 12 wherein said generating a protective action signal comprises at least one of initiating a trip event, triggering an alarm, displaying status of said protected load and communicating said protective action signal to a centralized monitoring station.

17. The intelligent electronic device of claim 12 wherein said non-electrical characteristic comprises at least one of a humidity, a temperature and a pressure.

18. The intelligent electronic device of claim 12 wherein said non-electrical characteristic signal comprises an analog signal.

19. The intelligent electronic device of claim 12 wherein said intelligent electronic device comprises an electronic trip unit.

20. An intelligent electronic device for monitoring non-electrical characteristics of a protected load, said intelligent electronic device comprising:

a sensor generating a non-electrical characteristic signal indicative of said non-electrical characteristic of said protected load; and

a signal processor responsive to said non-electrical characteristic signal, and having a memory for storing signals including program signals defining an executable program for:

processing a relationship of said non-electrical characteristic signal for analysis purposes, and

generating an action signal when a predetermined analytical threshold is reached.

21. The intelligent electronic device of claim 20 wherein said processing includes at least one of:

predicting most likely future non-electrical faults,

prioritizing maintenance requirements of protected loads, and

determining load life.

22. The intelligent electronic device of claim 20 wherein said processing comprises communicating said relationship of said non-electrical characteristic to a remote monitoring device.

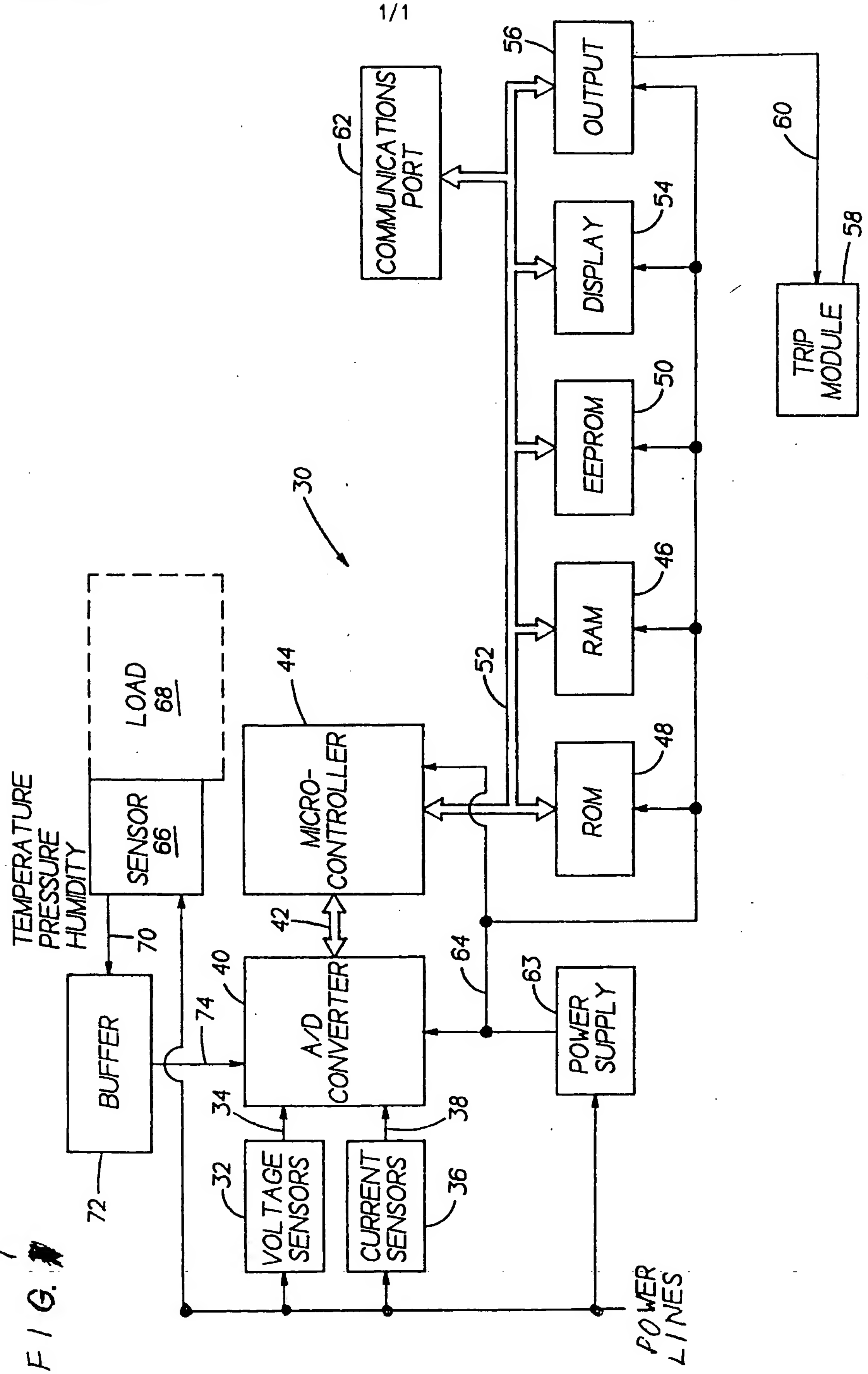
COMMUNICATIONS PORT
62
56
OUTPUT
DISPLAY
54
EEPROM
50
RAM
46
ROM
48
60
TRIP MODULE
58
30
LOAD 68
44
MICRO-CONTROLLER
52
TEMPERATURE
PRESSURE
HUMIDITY
SENSOR 66
70
42
BUFFER
72
74
40
A/D CONVERTER
64
63
POWER SUPPLY
34
38
VOLTAGE SENSORS
32
CURRENT SENSORS
36
POWER LINES

FIG. 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/14409

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G05B23/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 502 435 A (RALSTON DOUGLAS E) 26 March 1996 (1996-03-26) column 3, line 16 -column 5, line 34 ---	1,3,5-7, 9 2,4,11
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2000	13/09/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Kelperis, K

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/14409

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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